SPINEL GRAINS IN UNEQUILIBRATED L CHONDRITES (L3.1, L3.4, AND L3.7): PRELIMINARY DATA FOR CLASSIFICATION OF FOSSIL METEORITES. James L. Holstein[1,2], Birger Schmitz[1,2], and Philipp R. Heck[1,3], [1]Robert A. Pritzker Center for Meteoritics and Polar Studies, Department of Science and Education, The Field Museum of Natural History, Chicago, IL, USA jholstein@fieldmuseum.org, [2]Division of Nuclear Physics, Lund University, Lund, Sweden, [3]Chicago Center for Cosmochemistry, The University of Chicago, Chicago, IL, USA.

Introduction: To date, about 100 fossil meteorites (1-21 cm in diameter) have been recovered from mid-Ordovician marine limestone in Sweden. The more common silicate minerals in the fossil meteorites are altered during diagenesis and replaced by barite, calcite, and phyllosilicates [1]. This prevents classification of the meteorites under the current schemes. However, some spinel group minerals do survive this process unaltered. Using spinel group minerals recovered from mid-Ordovician sediments and fossil meteorites, methods were developed to classify meteorites and reconstruct the variations of the meteoritic flux in Earth's past [2]. Studies of the chemistry and isotopic composition of spinel grains from the mid-Ordovician fossil meteorites found that they are all or almost all L-chondritic in nature [3-5]. The maximum sizes of the spinel grains show that all the petrologic types in the range 4 to 6 are present, but no unequilibrated chondrite has so far been documented. The fraction of modern unequilibrated L chondrite meteorites is high enough that one would expect to find evidence of this group in the fossil record if this fraction was the same. A study of the CM chondrite Acfer 331 [6] and of winonaites [7] demonstrated that elemental compositions of spinel-group minerals in modern meteorites could be diagnostic in the classification of fossil meteorites other than equilibrated L chondrites in ancient sediments.

Here, we present a systematic study of spinel group minerals in modern unequilibrated L chondrites. An improved understanding of this spinel fraction could be instrumental in identifying the first unequilibrated chondrites in the assemblage of fossil meteorites.

Samples and Methods: In this study, 2-4 grams each from a suite of unequilibrated L chondrites, LEW 86018 (L3.1; NASA JSC [8]), Hallingeberg (L3.4), and Mezö-Madaras (L3.7; FMNH ME 1607.15), were dissolved in HF and HCl solutions and the acid resistant grains were recovered. The majority consisted of three mineral phases from the spinel group: Mg-Al spinel, Cr-spinel, and chromite. Abundances and grain diameters of these three groups were quantified and their chemical composition determined with the Field Museum's Zeiss Evo 60 SEM and Oxford INCA EDS system.

Results: In total, 2002 grains of Mg-Al spinel, Cr-spinel, and chromite were recovered. The abundance of chromite decreases with decreasing petrologic type from 70% in Mezö-Madaras (L3.7) to 27% in LEW 86018 (L3.1). There is no clear trend in the abundances of Mg-Al spinel and Cr-spinel relative to petrologic type (Fig.1).

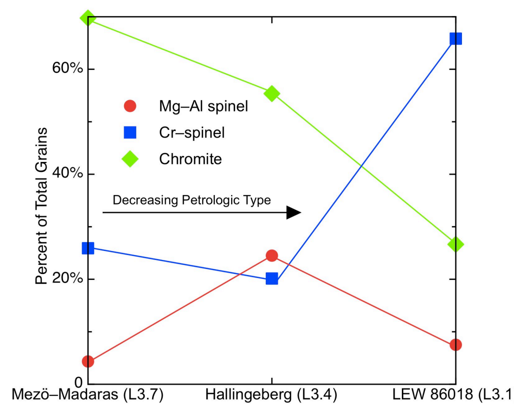

Fig. 1. Abundances of spinel group mineral phases relative to petrologic type.

The average grain diameter of chromite and Mg-Al spinel decreases with lower petrologic type (Fig. 2).

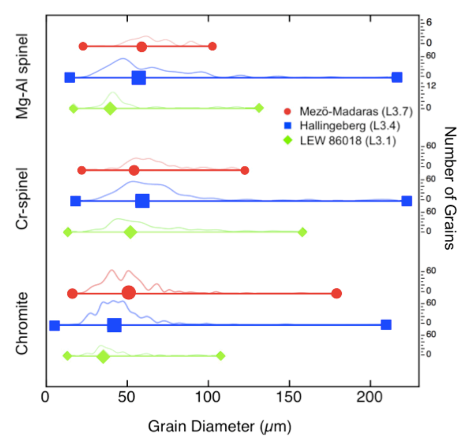

Fig. 2. Grain size distribution and abundance of spinel mineral phases relative to petrologic type.

The average grain diameter of chromite ranges from 50 µm in type L3.7 to 35 µm in type L3.1 and the average of Mg-Al spinel ranges from 59 µm to 39 µm in types L3.7-L3.1, respectively. There is no clear trend of grain size with petrologic type in the Cr-spinel grains.

Some individual grains exhibit heterogeneity in their major element compositions. The percentage of grains that exhibit intra-grain heterogeneity increases with decreasing petrologic type (Fig. 3).

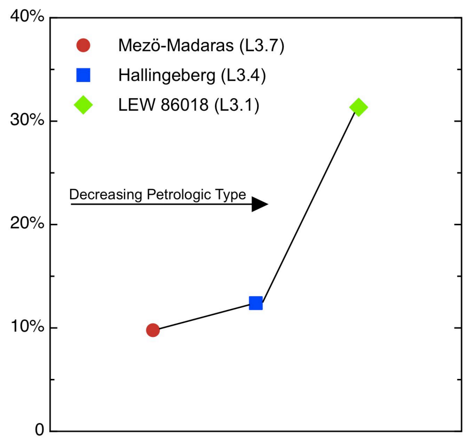

Fig. 3. Percentage of grains that exhibit heterogeneity.

The average MgO content is higher and the average FeO content is lower in Cr-spinel grains from the lowest petrologic type 3.1 than in types 3.4 and 3.7 (Fig. 4). MgO and FeO content of chromite and Mg-Al spinel grains tend to be similar among the three petrologic types in this study.

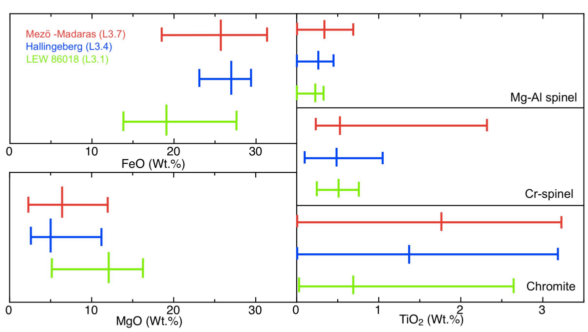

Fig. 4. MgO and FeO compositional range and average in Cr-spinel (left) and compositional range and average of TiO_2 in the three mineral phases (right).

The average TiO_2 content increases in chromite and Mg-Al spinel relative to increasing petrologic type. The compositional range of TiO_2 increases in all three mineral phases with increasing petrologic type (Fig. 4).

Discussion and Conclusions: Abundances of chromite, average grain diameters of chromite and Mg-Al spinel as well as the fraction of heterogeneous grains could potentially be used as a petrologic indicator. This is what is expected based on observations in previous studies of chondrites that experienced different degrees of thermal metamorphism (e.g., [4]). The average MgO and FeO content in Cr-spinel could be an indicator of lower petrologic types. In a population of Cr-spinel grains from the lowest petrologic type in this study, the average MgO content is typically higher and the FeO content is typically lower. Also, the upper limit of MgO concentration in Cr-spinel grains from types 3.4 and 3.7 is no higher than 12 wt%. If the studied meteorites are representative of their class and petrographic type, it would lead us to believe that any Cr-spinel grains with an MgO concentration greater than 12 wt% may be of lower petrologic type. Likewise, the lower limit of FeO concentration in Cr-spinel grains is higher for the higher petrologic types than the lower type. If the FeO concentration is below 18.5 wt%, this may indicate a lower petrologic type. Though there is overlap in the content of TiO_2 among the three petrologic types in this study, the average TiO_2 composition of chromite and Mg-Al spinel increases and the compositional range increases in all three mineral phases with increasing petrologic type.

In order to distinguish between the different petrologic types we need to consider the range of compositions and sizes of many spinel-group grains. A single grain elemental analysis obviously does not allow us to unambiguously classify its source meteorite. We will test our classification method with other unequilibrated L chondrites and expand our database also to account for variability among L chondrites of the same petrologic type.

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